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Technical Lesson 53

PRINCIPLES OF ELECTRICALLY OPERATED TUNED R-F CIRCUITS

Inasmuch as the Atwater-Kent Model 40 circuit is typical of so many of the standard tuned radio-frequency receivers we shall make use of it to describe the various principles involved. A complete schematic diagram of the circuit and socket power unit is shown in Figure 1. Alternating-current tubes are used in the radio circuit and a full-wave rectifying tube is employed for the power supply. The complete assembly of sets of this type consists of the receiver unit proper and the power pack built into one compact unit on a metal chassis. The receiver consists of two stages of radio-frequency amplification in conjunction with an untuned antenna coupling circuit, a tuned detector, and two stages of audio-frequency amplification. With the exception of a few minor variations the detector and audio amplifier portions of the receiver are standard and similar to other models of this receiver. The receiver has its tuned radio-frequency stages synchronized and tuning is accomplished entirely with one dial. There are only three controls on the panel; namely, the power supply switch used to place the set in and out of operation or, as we most generally say, "to turn the set on and off," the station dial for selecting the program, and the volume control.

The power unit is designed for use on standard 110 volt, 50-60 cycle, alternating current lighting systems. A special model employing a specially designed power transformer is required where the frequency of the a-c supply is 25 cycles. The power unit receives an alternating current of one voltage, called the line voltage, through the attachment cord and changes this voltage to a-c voltages of lower orders, and d-c voltages of both high and low orders to supply complete plate, filament and grid voltages to operate the tubes in the receiver.

It is well to keep in mind that whenever receivers of this general type utilize three stages of tuned radio-frequency amplification, instead of two tuned stages as in this case, the circuits will not be basically different from each other. Therefore, when an additional tuned radio-frequency stage is built into a receiver the coils and condensers comprising this stage must be exactly similar to those of the other tuned stages. Thus, each tuned stage must possess identical electrical characteristics; that is, the output and input characteristics in which the tuned amplifiers function must be the same for each stage.

The tuned radio-frequency circuits are in themselves simple in design, each consisting of a vacuum tube working as an amplifier, a radio-frequency transformer, a variable condenser and additional unit or units for suppressing uncontrolled radio oscillations. The design of the units referred to immediately above is governed by the method used for combating the tendency of self-oscillations to be set up in a radio-frequency amplifier circuit. The method used in this receiver is known as the "grid suppressor" method and

makes use of a small resistor of approximately 800 ohms, inserted directly in series with the grid of the tube in the manner shown in the diagram. The energy in unwanted oscillations which may be set up due to the inter-electrode capacity of the radio tubes is dissipated by means of this resistor. Interelectrode capacity means simply, that in a high frequency amplifier tube the plate and grid are connected by electro-static lines of force which set up the difference of potential between these electrodes thus causing a small capacity to exist between them. A separate resistor is employed in each tuned amplifier which allows three stages to be brought into synchronism without fear of any undesirable coupling effects which very often are just right for setting up radio frequency oscillation.

Analyzing the schematic circuit depicted in Figure 1, it will be seen that all of the elements involving the receiver proper are shown above the dotted line while that portion of the drawing below this line represents the power unit which energizes the tubes in the receiver.

Tandem tuning of all three variable condensers marked C-1, C-2 and C-3 is possible, using a single control dial, because these circuits possess similar electrical characteristics. As we have just explained circuits of this kind are said to be adjusted accurately in phase when synchronism is established. It will be noticed that tube No. 1, the first radio amplifier, is coupled to the antenna system in such a manner that the signal energy collected by the antenna enters the set via the resistance, marked "volume control," and the antenna coupling transformer, and thence feeds directly to the grid of this tube.

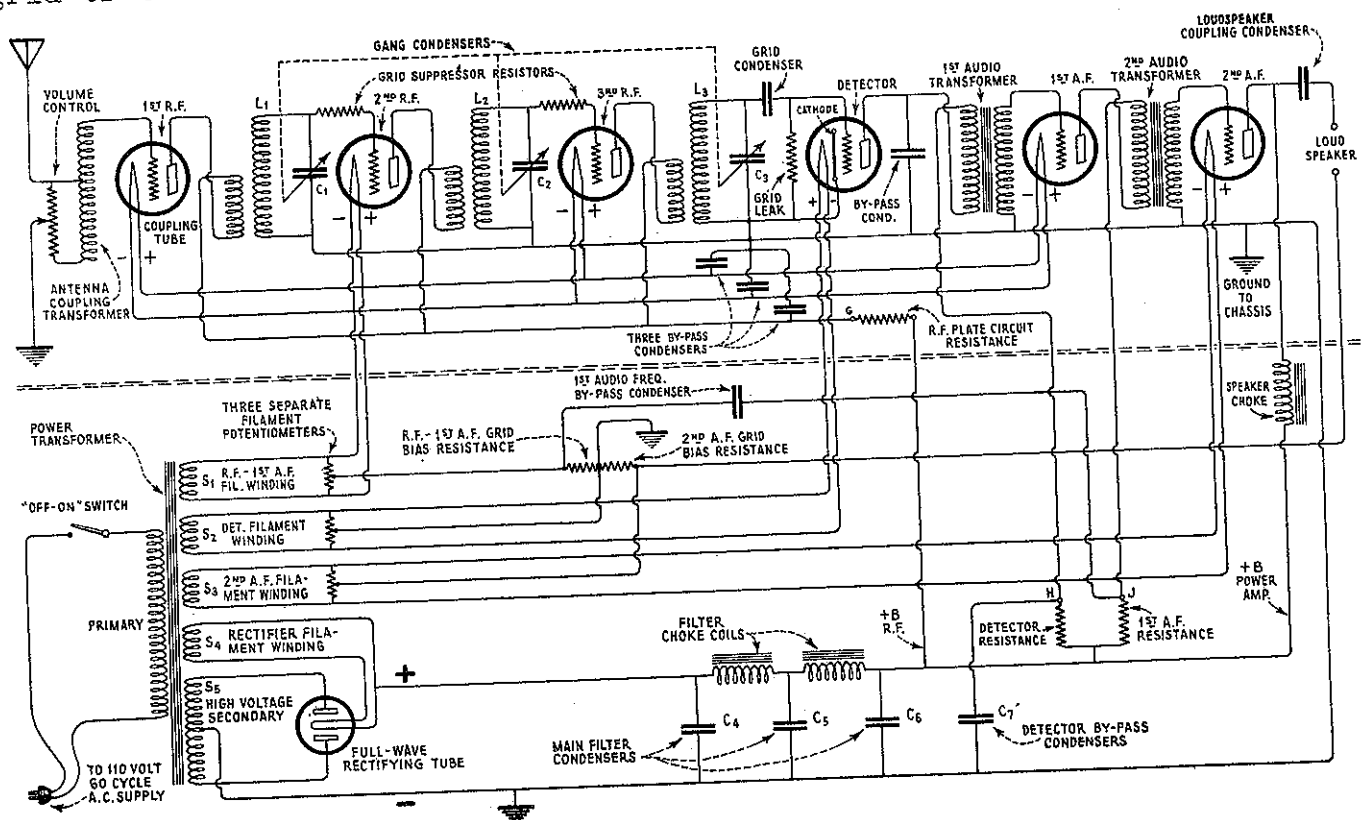


Figure 1

One should always keep in mind that the average antenna possess a somewhat high resistance and is therefore naturally broad in tuning, and consequently all of the broadcast frequencies are picked up by an untuned antenna of this type. The power or intensity of the signal can, however, be governed by the use of the volume control shown in the diagram. Larger signal voltages will be obtained from this unit when moving the adjustable arm in the downward direction. This is a condition to be expected when we recall that while current is flowing a greater voltage drop will be obtained from any device functioning upon the potentiometer principle when a greater number of turns of the resistance is used to supply voltage to the circuit being energized or, in this case, the coupling transformer and the first tube.

An untuned antenna of this design does not require a separate control, generally called a "trimmer," so as to compensate for any effect of the antenna circuit and permit accurate tuning. It is obvious that tuning is accomplished in this receiver only in the radio frequency circuits that follow the first tube. In brief, no adjustable tuning feature in the antenna system is needed because the first tube merely acts as a coupling device, its value as a radio amplifier being rather limited.

It has been mentioned in a foregoing paragraph that the untuned antenna responds to the signals of all stations whose frequencies lie within the broadcast range and that a separate tuning control for the antenna circuit is eliminated by utilizing the first tube in the receiver merely as a coupling device. Thus, when antennas of different lengths are installed with a receiver of this design there will not be any apparent detuning effects on the tuned radio frequency stages.

Let us now consider how the signal energy travels through the successive circuits in electrical impulses until it is finally transformed by the loudspeaker into acoustic energy or sound waves which faithfully reproduce the music or speech as originally rendered at the broadcast microphone. The modulated carrier wave emitted by a broadcast antenna strikes the receiving antenna and sets up an oscillating current in the conductors of the antenna system. This alternating current passing through the antenna coil marked "volume control" produces a radio frequency voltage of a certain amount across its turns, depending upon the position of the movable arm. This action has already been explained. The alternating voltage supplied by this coil is applied to the coupling transformer coil and to the grid or input of the first tube. The grid potential now alternates and varies in magnitude according to the signal characteristics, and the grid acting upon the electron stream in the tube causes corresponding variations in the amount of electrons reaching the plate; that is to say, the grid potential variations cause similar plate current variations, only somewhat enlarged. The plate current cannot reverse its direction of flow as does the oscillating current passing to the grid; the plate current simply rises and falls in strength according to whether the grid is excited with either a positive or negative alternation of a certain value.

The plate current, then, can be said to be a pulsating current which conveys all of the characteristics of the modulated signal wave. When a signal is being received the plate current varies in this way and it will be noticed that it must flow through the primary of the first radio frequency transformer since this winding is inserted in series with the plate circuit.

Hence, there is instantly established a fluctuating magnetic field about this winding which in turn induces a radio frequency voltage across the secondary winding of this transformer. It is in this manner that the signal is transferred from the plate or output of the first tube, into the grid or input of the second tube, the transformer acting as a resonant coupling device.

At this point in the explanation we desire to emphasize the fact that all broadcast signals intercepted by the antenna are scrambled up, as it were, and actually are represented in the pulsations of plate current of the first tube. However, it should be fully understood that the radio frequency voltage induced across the secondary will reach high values only for that particular signal whose frequency corresponds to the frequency at which the tuned circuit L-1, C-1 is set. Any frequency within the range of the receiver may be selected to the exclusion of other frequencies by varying the capacity of tuning condenser C-1, shunted across the secondary winding L-1. Of course, additional selectivity is obtained by the use of the two subsequent tuned stages of the radio amplifier system consisting of L-2, C-2 and L-3, C-3 respectively, through which circuits the desired signal passes until it reaches the grid of the detector. These amplifier stages serve to reduce the voltage of undesired frequencies while the resonant frequency, or frequency to which the circuits are tuned, will be increased in strength to an extent depending upon the gain in amplification of the second and third tubes.

From previous explanations two important facts concerning a conventional tuned radio frequency amplifier portion of a receiver should be understood; first, the signal voltages impressed upon the grid of a certain amplifier will be greater than the voltage on the grid of a preceeding tube by the gain in amplification provided by the preceeding tube and, secondly, the radio transformers between the tubes merely serve as resonant coupling devices which act to transfer the signal energy from one circuit to another. The principles of electromagnetic induction are applied in any active transformer; for example, let us consider the radio transformers in our circuit of Figure 1; here the changing magnetic field currounding each primary is set up by the pulsating plate current flowing through its turns and as this field links through the secondary turns a fluctuating voltage is induced therein which in turn causes an alternating current to traverse the tuned circuit comprising the secondary winding and variable condenser.

Thus it is evident that the capacities of the three tuning condensers are varied simultaneously to place the radio frequency circuits in resonance with the carrier frequency and when this is done the largest amount of signal voltage will be available for the excitation of the detector grid. The interior view of the receiver in Figure 2 shows the rotor plates of the three condensers C-1, C-2 and C-3 ganged together to provide one tuning control on the front of the receiver panel. One of the metal belts, linking the shafts of the first and second condensers is visible in the extreme lower left of the photograph. The other belt coupling the second and third condensers can just be seen toward the middle and below the edge of the metal panel supporting the three condensers. This view also shows the three interstage transformers (radio frequency transformers) mounted with their center axes at 90 degrees to one another in order to eliminate the possibility of undesirable coupling effects between these stages.

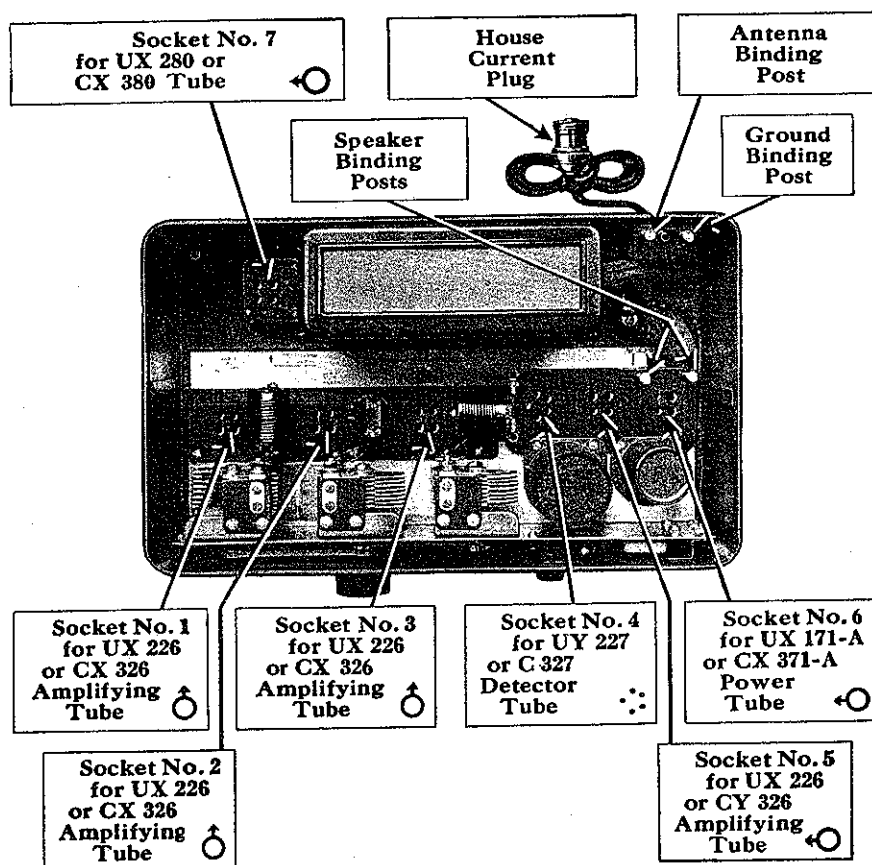


Figure 2

As we already stated, the grid suppressor resistors used in the second and third amplifiers are for the purpose of stabilizing these circuits, thus preventing self-oscillation.

We will now discuss some points regarding the operation of the detector tube working in conjunction with the grid condenser and grid leak resistance. When signals are not being received the detector plate current flows steadily at a constant value, called the normal value, and depends for one thing upon the value of the leak resistance. This resistance has an automatic controlling effect upon the plate current for the following reason. During normal operation of the tube a certain quantity of electrons liberated by the hot cathode in their travel toward the positively charged plate actually strike and collect upon the fine coil wire comprising the grid and, once upon the grid, they cannot get off because the grid does not emit electrons, it being a comparatively cold element. The electrons are infinitesimally small particles of negative electricity. They are virtually trapped on the grid because the grid condenser acts as a barrier to the flow of a current of electricity (remember that the movement of electrons through a conductor constitutes a flow of current) and therefore their only path of escape back to their source, the hot cathode, is through the high resistance leak. Now, this leak has such a large value of resistance, in the order of one or two megohms, that when the correct value is used the electrons flow through it at a very slow rate (compared to the high frequencies). Hence, a uniform

quantity of electrons are always held back, thus maintaining the grid at some predetermined negative potential. The detector grid, then, is slightly negative to begin with even though signals are not coming through.

When a signal is tuned-in the voltage is impressed across the tuned circuit L-3, C-3, which is the input circuit to the detector, and the grid condenser permits this alternating voltage to pass through readily to the grid. But we must now consider the effect of this signal voltage on the grid while the grid is already slightly negative and continues to add electrons to itself and which pass off slowly through the grid leak. Let us suppose for a moment that the grid leak be removed and that the incoming signal causes the grid to be charged alternately positive and negative. Now since the grid is held at some negative value the actual potential it assumes at any time is the difference between its negative voltage, due to electrons collecting upon it, and the amount of the positive and negative signal voltages; i.e., the amplitude of the incoming wave. What happens then is that the grid potential fluctuates, becoming alternately more negative than positive because positive signal voltages cause the grid to attract electrons in large quantities thus augmenting the number which normally collect upon it due to the position it occupies between the cathode and the plate.

In any event the grid potential becomes increasingly negative which effect is repeated in the plate current. That is to say, the rise and fall values or voltage amplitudes actually on the grid become alternately more negative than positive. In fact, with efficient detector design these values are all thrown or shifted over toward the negative side which simply means that the grid is actually charged to greater or lesser degrees of negative. As we have just mentioned the plate current is affected by variations in grid potential; a negative grid causes a reduction in the plate current. Furthermore, the varying grid causes the plate current to rise and fall and its instantaneous values or amplitudes at any moment will be less than the normal flow. This action is known as the "detection characteristic" because the plate current is made to drop to a considerable extent from its usual normal value by the grid's influence. Or in other words, the current variations in the plate circuit decrease more than they increase which result gives us an average current change whose wave form corresponds to the wave form of the modulation component of the incoming signal. This average change is called the "audio frequency component" since it conveys the intelligence to be communicated, and if this plate current is now made to flow through telephone receivers it will set up a varying magnetic field about the windings which will act upon the diaphragms to produce audible sound waves. Thus the presence of the signal energy in the receiver is detected. It can then be said that the detector serves to separate the modulation component of an incoming signal wave from the carrier or high frequency component.

If an audio transformer primary is inserted in the detector's plate circuit, as is the case in our circuit under discussion, the current variations will set up changing magnetic lines of force permeating the iron core which will produce corresponding voltages in the transformer secondary, and these, in turn will be applied to the grid of the tube following the detector. This tube is known as the first audio frequency amplifier and its sole purpose is to strengthen the signal voltage it receives from the detector output without in any way altering the peculiar wave form of the modulation

frequency which represents the voice of music being broadcast.

The following brief remarks will no doubt prove sufficient to explain the effect upon the received signal when the grid leak is not of the correct value. The proper amount of resistance necessary for a grid leak must be carefully determined when designing a receiver. If the grid leak is too high, electrons cannot escape from the grid rapidly enough, resulting in the accumulation of a large negative potential on the grid which will soon block the flow of plate current on strong signals. On the other hand, a grid leak whose resistance is too low, and therefore also unsuited for the particular duty which it is supposed to perform, will allow electrons to leak off too rapidly and, in this case the grid will not become sufficiently negative at any time to force the plate current to undergo a large variation from its normal value. Naturally a plate current changing within only narrow limits is capable of producing but a small change in magnetism in the reproducing unit or in the audio transformer, thus resulting in the reception of a weak signal. The object then, in all detector action, is to cause the plate current to vary between the greatest limits in order to produce the largest possible change in magnetism in the windings which carry the plate current. From the foregoing we can see that it is not the actual value of plate current in a detector output, or for that matter in an audio amplifier output, that determines the strength of the signal, but it is the extent with which this current can be made to change in order that it may ultimately cause large deflections or movements of the diaphragm of the reproducing unit to act strongly upon the surrounding air. Note that the small by-pass condenser connected between plate and ground in the detector, as shown in Figure 1, provides a resonant path for the carrier frequency to pass through, and when thus removed from the audio amplifying system this high frequency energy cannot possibly cause undesirable effects in these circuits.

Reference to the schematic diagram shows that conventional transformer coupling is employed in the audio amplifier system and an output choke and by-pass condenser is provided, across which are located the speaker binding posts. The by-pass, or coupling condenser, is inserted in the lead attached to the top of the choke. This form of coupling is used to prevent the plate direct current of the power tube from passing through the loudspeaker coils.

The largest amount of signal voltage is built up through the audio transformers by the use of the soft iron core, for a large magnetic flux will circulate through the iron for a given plate current variation. The final audio stage employs a power tube of the UX-171A or CX-371A type in order that the signal strength will be raised to its maximum audible amplification, thus assuring ample power and an undistorted output. There is no polarity to the output current from the coupling condenser through the loudspeaker winding and therefore the latter should be connected in the manner that affords the most pleasing reproduction.

The following paragraphs relate to the various circuit functions incidental to a-c. operation.

The parts comprising the power unit assembly are the power transformer, with its single primary winding and five secondaries, the voltage divider resistances, filter choke coils and condensers, and the full-wave filament type rectifier tube, all arranged in the circuit according to the diagram in Figure 1.

All of these parts, with the exception of the rectifying tube and its socket, are incorporated in a compact unit located in a metal can as shown in Figure 2, the cover acting as a shield as well as to house the parts. In regard to the use of metal cans let us offer this suggestion. If at any time a receiver or power unit is encountered where certain parts are imbedded in sealing compound and form a block or section and, in the event such parts are found to be defective, it is suggested that no attempt be made to repair the damaged block but that it be removed and replaced by a perfect one. Usually only factories and main district service stations have the facilities for repairing special parts made up in this manner.

The power transformer winding, which is connected to the house lighting circuit, is known as the input or primary. Alternating current passing through the primary winding creates a magnetic flux which permeates the laminated iron core and these lines threading through the turns or wires of the several secondaries, or output windings, set up an alternating current in each of them at some certain voltage. The voltage in each case is governed by the ratio of turns in the primary and secondary windings. The output voltage will be stepped up if the secondary has more turns than the primary, whereas the output voltage in the secondary will be stepped down to a value less than that applied to the primary providing the secondary is wound with less turns than the primary. This voltage transformation and its dependence upon turns ratio is directly applicable to any windings found on the transformer.

In previous lessons it has been explained that power transformers utilized in a-c receiving sets are made in two types, either for half-wave or full-wave rectification, and the difference between the two is merely in the design of the winding supplying the high plate voltage. A half-wave system employs a single continuous winding and the full-wave system a split winding with a midtap which forms the negative d-c. side of the rectifier output. Full-wave rectification is used in the circuit in Figure 1, the plate winding being identified by the mark S-5. Reference to this diagram shows that each outside connection of S-5 leads to a plate or anode of the full-wave rectifying tube. By this center-tapped arrangement each half of winding S-5 supplies the required plate voltage to its respective plate in the tube. For example, a transformer of this type designed for use with a UX-280 type rectifier will deliver about 300 volts a-c. from each half of its split plate winding. The filament of the rectifier is supplied with its requisite terminal e.m.f. by the winding marked S-4.

The UX-280 consists of two plates associated with two filaments, each plate surrounding a filament. The filaments are connected in series, thus if either filament burns out the tube becomes totally inoperative. If the tube were not so constructed, but the filaments were in parallel, then perhaps the tube might at sometime or another struggle along performing only half its duty in the event one filament became damaged. In the diagram we show only one filament for the rectifier tube when, as a matter of fact, there are actually two, this being done in order to simplify the drawing.

The filament circuit of the rectifier serves as the positive d-c. side of the rectifier output. Observe at this point that S-4 does not carry a tapped resistor shunted between its terminals as do the other three secondaries shown above S-4. A resistor is not required because this portion of the circuit

is used merely to energize the filament of the rectifier, and effects classified under the term "hum" do not demand consideration in this case. However, when a secondary winding supplies the filament of a-c. tubes in the receiver, then this "hum" effect becomes a very important consideration. Consequently, the three secondaries, S-1, S-2 and S-3 utilized to supply the filament heating current to the receiving tubes are shunted by separate potentiometer resistors, each being mid-tapped so that an exact electrical balance in these circuits may be found which is absolutely necessary for the elimination of "hum" in the loudspeaker.

Let us now turn our attention to the rectifier tube and the filter system attached to its output. A fairly high alternating voltage of 60 cycles in the secondary S-5 is applied to the plates of the rectifier in the manner heretofore explained, thus each plate alternately receives a positive and negative potential but only that plate which is charged positively will be active in attracting electrons emitted by the filament and pass current through the line. As each alternation or half-cycle is applied to the rectifier it delivers a pulse of direct current through the external circuit from positive + to negative - according to the signs as shown in the diagram. A better understanding of this action will be obtained by observing the arrows in Figure 3 which indicate the direction of current flow through the system. The pulses of direct current are unsuited for excitation of the plates of the receiving tubes for they would set up a very objectionable humming sound in the loudspeaker. Hence, this pulsating or undulating current from the rectifier must be smoothed out to provide a substantially steady flow of direct current and it is here that the combined filter chokes and filter condensers C-4, C-5 and C-6 are given a very important task to perform. The action of this filter network is briefly as follows: The laminated iron core choke coils build up strong magnetic fields which tend to oppose any change of current flowing through them, this effect being due to the self-inductance of the chokes; that is, the magnetic lines of force produced by the changing current act upon the same turns which are responsible for setting up the lines and induce in these conductors, or turns, a voltage, called reactance voltage, which tend to prevent either an increase or decrease

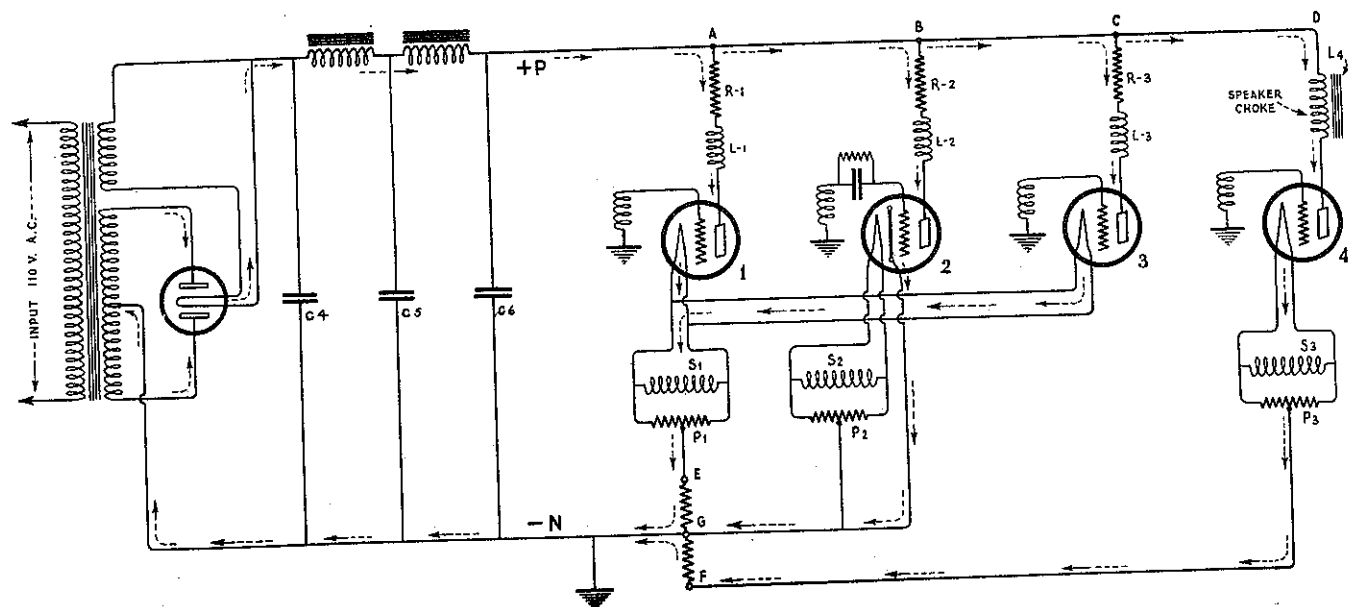


Figure 3

in the current strength. The reactance voltage induced in the circuit, because of this inherent opposition offered by the chokes, charges the filter condensers. Whenever the current tends to decrease through the chokes, as during the decay of current in each pulse of rectified current, the charged condensers give up their stored energy and furnish a new voltage to the d-c. line which maintains the voltage at a practical constant value. Remember that the stored energy in the condensers was placed there by the reactance voltage generated during a previous increase in the rectified pulsations. It is essential that a choke coil possess two properties in order to obtain the desired filtering action; i.e., in order that the filter output be a pure d-c. First it must possess a high inductance with the direct current passing through it obtained by using a winding of many turns on an iron core, and second, it must not allow its core to become saturated with magnetism. A saturated core will not lose and take on magnetism quickly due to hysteresis, which is essential to the building up of a reactance voltage upon which the whole system functions. This means that a saturated core will not act strongly to prevent slight variations in current and therefore the d-c. output would not be free from the slight ripple, known as the a-c. component. Furthermore the d-c. resistance of the choke must be comparatively low or else a large voltage drop will occur across the choke winding with consequent reduction in the output voltage. An air gap of sufficient width in series with the iron magnetic circuit reduces the possibility of saturation. It is for these reasons that a defective choke coil in a power unit should always be replaced with one possessing similar electrical characteristics. If an improper choke coil be used, for instance one rated at a lower current carrying capacity than the original choke it replaced; for example, one rated to carry only 60 milliamperes where a 125 milliamper choke is required, the following results would be sure to happen: The flow of excessive current would overheat the winding and perhaps damage the insulation, the core would become saturated, thus lowering the coil's effective inductance with a consequent reduction in filtering action. The latter condition would become apparent at once by the presence of a noticeable fluctuation of d-c. voltage and subsequent "hum" in the loudspeaker.

We made mention of the three filter condensers in a previous paragraph, but let us here state more precisely the function of each one in turn. A filter network like the one shown in Figure 1, consisting of two chokes and three capacities C-4, C-5 and C-6, is known as a "brute force filter." This is the conventional filter arrangement found in a large majority of a-c. receivers in use at the present time. Before proceeding with the individual functions of the condensers let us mention that any ripple in the d-c. will be impeded by the choke coils, and the condensers will each act similarly in reducing this ripple because they offer a path of low impedance (low opposition) to a-c. energy. It is to be understood that the ripple voltage and the current it sets up is the a-c. component. Hence, all condensers in a filter system will be effective to a certain extent in by-passing the a-c. component in the rectifier's output. The first condenser C-4 serves as a reservoir condenser for the output of the rectifying tube because of its ability to store up energy at one time and later return this energy to the circuit, thus contributing, in a measure, to the satisfactory regulation of the voltage. Also, as we just mentioned, this condenser provides a path of low impedance (low opposition) to the a-c. component. Condenser C-5 aids

in the filtering process by by-passing any ripple not effectively removed by the first choke, and by-passing any ripple or reactance voltage set up by the impeding action of the second choke. Condenser C-6, being adjacent to the voltage dividing circuit supplying the tubes of the receiver, is known as the output condenser and should be one whose capacity is quite large, higher than perhaps 2 or 4 mdfs. of capacity. This condenser not only serves in the manner outlined for the other condenser to by-pass whatever ripple may be present at this point in the circuit, but it has a far more important duty in the whole scheme because it has a considerable influence upon the tone quality of the reproduced broadcast program. This is easily understood when we stop for a moment and consider the constantly changing requirements imposed upon the radio frequency and audio frequency tubes. At times the grids of these tubes are impressed with large voltage swings which demand full plate current. If the plate current supply is adequate to meet unusual demands then we might say that it is capable of faithfully repeating the characteristics of any signal voltages delivered to the grid. It stands to reason then that in practical operation of a receiver, an additional supply of current must be provided at times from some source. This source is the stored energy in the output condenser; it gives up energy at such moments, hence we may call this condenser a "tank" condenser. All of the condensers should have a d-c. working voltage at least equal to the peak voltage output of the transformer. About 400 volts rated d-c. working voltage is a satisfactory rating to prevent possible rupture of a filter condenser used with a power transformer designed for supplying a 171-A power tube. In the event of a condenser breakdown, and where this part is accessible and can be removed the new condenser should not be used unless it has the capacity and d-c. working voltage rating of the damaged condenser. In many receivers these condensers are all mounted in a compact unit and sealed and cannot be individually replaced when damaged. As we have mentioned previously in the set under discussion the power unit is sealed in a single metal container, or can.

Now we will consider the general facts pertaining to the distribution of the d-c. voltages to the plates of the receiving tubes and the method employed for supplying the requisite negative grid bias voltages, for instance, by causing the plate current of a certain tube circuit to flow through a suitable resistance and thus obtain a voltage drop across the resistance. This method of obtaining a desired voltage by utilizing the drop of potential across a resistance may be easily understood by recalling the terms of Ohm's Law. This well known and valuable law tells us that the drop in potential across any part of an electric circuit is equal to the resistance of that part in ohms multiplied by the current in amperes flowing through the part. The student should be sure to understand this law and what we mean when we say "the voltage drop across a certain part is governed by the resistance of the part and the current passing through it." Thus, by a simple mathematical calculation, we need only to multiply current in amperes times resistance in ohms to find the voltage drop across any conductor of electricity. The procedure can be carried out for all kinds of resistance irrespective of size and form. The d-c. voltages obtained from the output of any rectifier and filter system is an application of this law. Of course, in order to calculate a resistance value which will give a predetermined voltage drop across it, one must first ascertain the amount of current that will be taken by the circuit in which the resistance is placed.

In the circuit in Figure 1 several resistors are inserted in series with plate leads and proper connections made to supply four values of positive plate voltage, which are approximately as follows: 44 volts to the detector plate obtained at point H through the drop in voltage across resistor marked "detector resistance"; 155 volts to the first audio amplifier obtained at point J through the voltage drop across the resistor marked "1st. A.F. resistance;" 160 volts to plates of all radio frequency amplifiers obtained at point G through the voltage drop across resistor marked "R.F. plate circuit resistance," and 180 volts to the power tube from the point at the output of the second choke, this being the high voltage side of the rectifier output. A slight loss in voltage, or voltage drop, will be accounted for across the chokes when the total current of the device flows through them, but this voltage will not be sufficient to cause any marked reduction in available voltage and the whole combination is carefully designed to allow for such fixed circuit conditions.

All of the filaments of the receiving tubes operate on raw a-c. and it is essential that the a-c. voltages obtained from the secondaries S-1, S-2 and S-3 be correct for the individual tubes. Alternating current tubes of the UX-226 or CX-326 type with a four-prong base are used in all radio frequency stages, and in the first audio amplifying stage. These filaments are arranged in parallel as shown in Figure 1, and connect to secondary S-1 which supplies approximately 1.45 volts a-c. with each filament drawing about 1.05 amperes. The detector tube, type UY-227 or C-327, with a five-prong base, is known as the "Cathode Heater" type, its filament being used merely to indirectly heat the oxide coated cathode which, when heated to a predetermined temperature, becomes the source of the electron energy. The filament is called the "heater" and it operates at an e.m.f. of about 2.35 volts a-c. from heater winding S-2. The UX-171A or CX-371A power amplifier tube in the second audio frequency or output stage operates satisfactorily when either a-c. or d-c. is supplied to its filament. In this circuit, of course, a-c. is supplied for this tube from winding S-3 with an output of about 4.8 volts. In order to have a good understanding of the method used for obtaining the grid biasing potentials of all the tubes, with the exception of the detector, we have rearranged the circuit as shown in Figure 3. This circuit can be readily interpreted after a few minutes of careful examination for it is evident that we have shown only the portions of the receiver and power unit in which we are immediately interested. Moreover, this diagram shows by means of arrows how the direct current flows through the system including the different plate circuits. The total direct current from the rectifier is available at point +P, the high potential side of the system. The total current flowing from this point divides at A, B, C and D, and the separate plate currents after passing through these branches again reunite and we find the total current flowing at point -N, the low potential side of the system. The sum of the currents drawn in branches A, B, C and D equals the total current output of the rectifier.

Let us analyze the circuit beginning with branch No. 1. Although this branch shows only one set of circuit elements yet it is intended to represent the plate circuits of the three radio frequency amplifiers. R-1 is the series plate resistor used to drop the voltage at "A" to the specified value for these plates, or 160 volts; L-1 represents the radio frequency transformer primaries of these tubes, while S-1 and P-1 indicate the filament winding on the power transformer and the potentiometer used for "hum" balance. Resistance between E and G makes it possible to obtain a suitable biasing

voltage for the grids of the radio amplifiers and first audio amplifier. The value required is approximately 13 volts. Notice that the plate current drawn by these four tubes flows through resistance E G and hence to -N side of the circuit and thus causes a voltage drop across this resistance. The polarity of this voltage is negative with regard to the negative side, -N side, of the circuit.

Similarly, if we wish to obtain a second value of grid bias we have merely to employ a second resistance, which in this case is resistor G F, inserted in the plate return lead of the power tube. This branch is marked No. 4. L-4 is the speaker choke, while S-3 and P-3 are respectively the filament heating winding and potentiometer used for "hum" balance. The principles involved in obtaining a voltage drop of any required value are again applicable and accordingly we may repeat that the plate current of the power tube flowing through resistor E G causes a drop in voltage between points E and G. The value this time is about 45 volts.

Branch No. 3 is the first audio amplifier circuit; the tube takes its filament supply from S-1 which also feeds the tubes in branch No. 1, as we have already explained. L-3 is the primary of the second audio transformer and R-3 the series plate resistance used to drop the voltage at B to the specified value for the plate of the first audio amplifier tube. Observe that all of the grids are grounded and therefore are actually connected to point G since this part of the circuit is also grounded.

Branch No. 2 is the detector circuit. Inasmuch as grid condenser and grid leak detection is employed it is obvious that under such condition a biasing voltage is not required. Hence, we find the grid return grounded and thus connected in effect directly to the cathode since this electrode is also grounded. We have attempted to illustrate how the continuity of the plate circuit is completed by drawing a wire from the cathode down to mid-tap wire of P-2 and thence to point G and to -N. all of this portion of the detector circuit is grounded, consequently no actual wires will be found between portions of related circuits in the receiver whenever ground returns are used. The continuity of any plate circuit can be easily traced by following the arrows. For instance, plate current of the detector flows from point B through R-2, the series resistor used to drop the d-c. voltage a specified amount in order to obtain the correct voltage for energizing the detector plate. Then the plate current continues through L-2, the first audio transformer primary, then to the cathode, the electron emitting electrode, down to point G to -N and thence through the plate winding of the power transformer, through the rectifying tube, through the two chokes to point +P and now returns to B, the place from whence we started this little excursion through circuit No. 2. Note that the filament of the cathode-heater type tube in branch No. 2, and its heater winding S-2 and potentiometer P-2, are not actually considered a component part of the radio frequency circuit, or grid circuit. However, this is not the condition of affairs when a tube of the regular type is used for the detector, because the hot filament in this case is actually the source of the tube's electron energy. Here the filament bears a direct relation to the grid circuit.

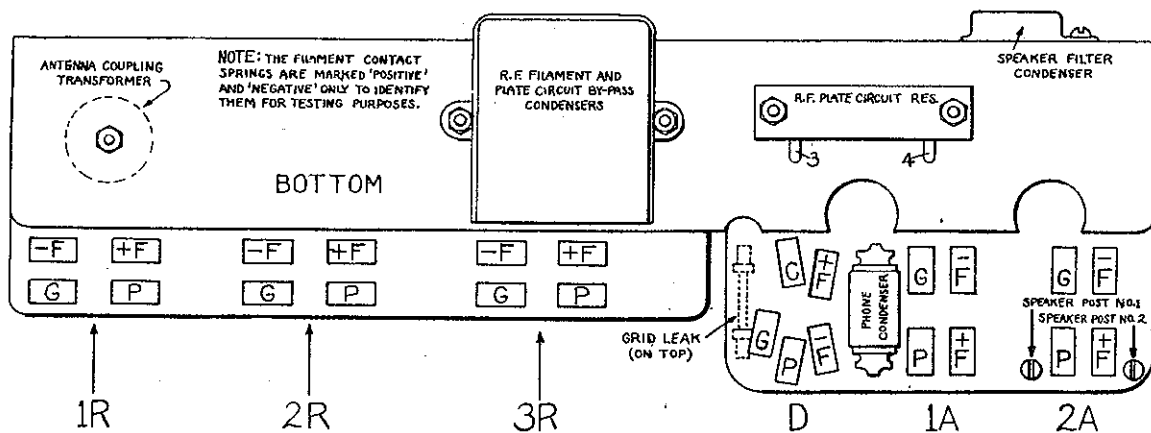


Figure 4

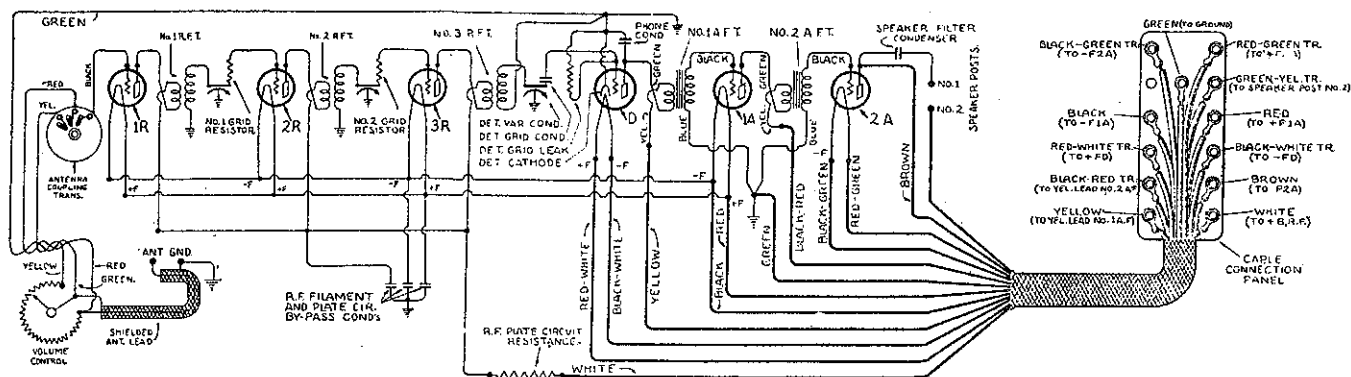


Figure 5

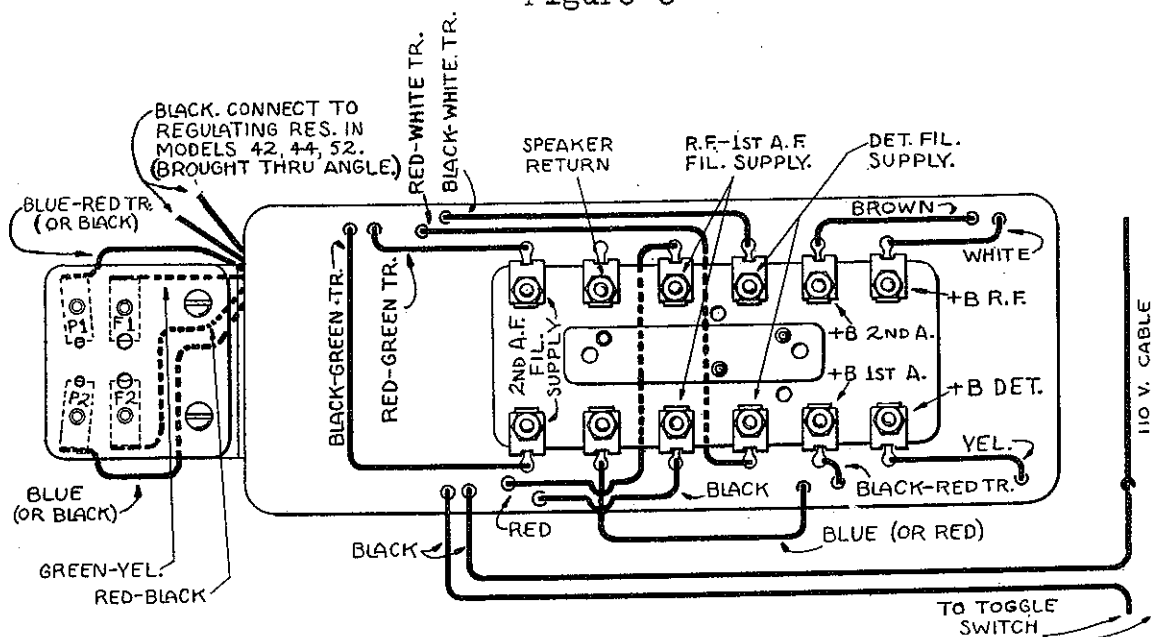


Figure 6

SERVICING

In the event that either the receiver or power unit develops trouble the numerous tests given in the following continuity test tables will be helpful in expediting service work. In Figure 4 we have shown the layout of the tube sockets, the filament contact springs being marked "Positive" and "Negative" simply to identify them for testing purposes. Figure 4 is to be used in conjunction with Figure 5, which is the wiring diagram of this model. The colors indicated in the first column of the test chart refer to the cable leads, as indicated on the wiring diagram in Figure 5. Before conducting any of the tests suggested in the charts first remove all tubes and the cable connection panel from the power unit. These tests are very simple to perform since a minimum of equipment is required. The test circuit should consist of test leads, a good grade voltmeter and "C" or "B" battery connected in series. The voltmeter used should give nearly a full scale deflection when the test points are touched. The view in Figure 6 shows the approximate position of leads in the power unit from the sealed container to the panel assembly rectifier socket, and so on.

CONTINUITY TESTS FOR RECEIVER

Locations on which test points are to be placed		Correct Indications	Circuit Condition. Wrong Reading Indicates			Remarks and Further Possibilities
From	To	Meter Reading				
Red-Green tracer	+F2A	Full deflection			Open in cable or connection	Examine all leads and soldered connections at cable connection panel and set when incorrect meter indication is obtained
Black-Green tracer	-F2A	"	"	"	"	"
Red-White tracer	+FD	"	"	"	"	"
Black-White tracer	-FD	"	"	"	"	"
Red wire	+F1A	"	"	"	"	"
Black wire	-F1A	"	"	"	"	"
Green-Yellow tracer	Speaker Post No. 2	"	"	"	"	"

Green wire	Ground Post	"	"	"	"	"	"
Brown wire	P2A	"	"	"	"	"	"
White wire	No. 4 (shown on R.F. Plate Resistance)	"	"	"	"	"	"

Note: The location marks are interpreted as follows: For example, +F2A stands for the positive filament contact of 2nd audio amplifier socket; -FD stands for negative filament contact of detector socket, etc.

Green wire	PlA	No deflection	Grounded 1st A.F. plate circuit	
" "	PD	" "	Grounded de- tector plate circuit	Or shorted phone condenser
" "	P3R	" "	Grounded R.F. plate circuit	Or shorted R.F. by-pass condenser
" "	+F3R and -F3R	" "	Grounded R.F., 1st A.C. fila- ment circuit	"
" "	+FD and -FD	" "	Grounded de- tector fila- ment circuit	
" "	+F2A and -F2A	" "	Grounded 2nd A.F. filament circuit	
" "	G2R and G3R	Partial "	No reading indi- cates open grid resistor or second- ary of either or both 1st and 2nd radio freq. trans- formers. Full reading indicates shorted grid circuit	Tests should be made across re- sistors and secondaries separately (Re- sistors are mounted on back of R.F. variable condenser)
" "	G1R	Full "	Open antenna coupling trans- former	Volume control in full right position

"	"	G1A	Partial	"	No reading indicates open sec. of 1st A.F. transf.	Full reading indicates shorted secondary
"	"	G2A	"	"	No reading indicates open sec. of 2nd A.F. transf.	Full reading indicates shorted secondary
"	"	Stator plates of detector tuning condenser	Full	"	Open secondary of last R.F. transformer	
"	"	CD	"	"	Open cathode lead	
White wire		No. 3 (on R.F. plate circuit res.)	Partial	"	No reading indicates open R.F. plate circuit resistance	Full reading indicates shorted R.F. plate circuit resistance
"	"	P1R, P2R and P3R	"	"	No reading indicates open primary of 1st, 2nd or 3rd R.F. transf.	
Yellow "		PD	"	"	No reading indicates open primary of 1st A.F. transf. (or open in cable connection)	Full reading indicates shorted primary
Black-Red tracer		P1A	"	"	No reading indicates open primary of 2nd A.F. transf. (or open in cable connection)	Full reading indicates shorted primary

NOTE: ADDITIONAL TESTS

Ground	Stator plates of detector tuning condenser	No	"	If reading is obtained it indicates shorted grid condenser	This condenser is mounted on back of det. tuning condenser
P2A	Speaker Post No. 1	"	"	Reading indicates shorted speaker filter condenser	

GLR	Ant. terminal	Full deflection	No reading indicates open antenna connection	VOLUME CONTROL. NOTE: Inspect the volume control carefully. Bend the slider so it makes firm contact with resistance wire. Clean the contact end top edge of the resistance unit and always use a slider of latest type for replacement
To test Volume Control unsolder Red lead from Antenna Coupling Transformer and test across Antenna and Ground terminals while turning the Control Knob.		Meter vane should deflect smoothly and give nearly full reading	No reading indicates open in resistance winding. Erratic reading indicates damaged resistance winding or slider	If the volume control is found defective, repair or install new control. Resolder Red lead

CONTINUITY TESTS FOR POWER UNIT

NOTE: The view in Figure 6 shows the locations referred to in this chart.

+B R.F.	+B 2nd A.F.	Partial	No reading indicates open speaker (output) choke	Full reading indicates shorted speaker choke
" "	+B 1st A.F.	Small	No reading indicates open 1st A.F. plate circuit resistance	
" "	+B Detector	Very small	No reading indicates open detector plate circuit resistance	
" "	Ground	No reading	Reading indicates shorted filter condenser	
" "	F1 (on Rectifier tube socket)	Partial	No reading indicates open plate supply filter choke	
Ground	+B Detector	No reading	Reading indicates shorted by-pass condenser	

"	One side of 2nd A.F. filament supply	Partial	No reading indicates open 2nd A.F. grid bias resistance	Full reading indicates shorted bias resistance
"	One side of R.F. and 1st A.F. filament supply	Partial	No reading indicates open R.F. or 1st A.F. grid bias resistance	Full reading indicates shorted bias resistance
"	One side of Detector Filament supply	Full reading	No reading indicates open connection to center tap of detector filament shunt resistance	Examine all connections under panel assembly
"	+B 1st A.F.	No reading	Reading indicates shorted by-pass condenser	
"	P1 and P2 (on Rectifier tube socket)	Nearly full deflection	No deflection indicates open high voltage secondary winding	
"	Each terminal of A.C. plug	No reading	Deflection indicates grounded primary of power transformer	Inspect A.C. cable and switch leads for accidental grounds

NOTE: ADDITIONAL TESTS

Test across the terminals of A.C. plug with toggle switch in "ON" position	Full reading	No reading indicates open primary of transformer or open cable or or switch leads
Test from F1 to F2 on rectifier tube socket	Full reading	No reading indicates open rectifier filament winding or connections
Test from one side of 2nd A.F. filament supply to speaker return terminal	Full reading	No reading indicates open connection to center-tap of 2nd A.F. filament shunt resistance

The chart appended below will be found especially convenient for quickly ascertaining the various important a-c. and d-c. voltages while the set is in operation. For measuring a-c. voltages use a 0-5 volt a-c. voltmeter and for d-c. plate and bias voltages use a high grade high resistance multi-scale d-c. voltmeter with suitable ranges to cover the tests.

VOLTAGE TEST CHART

<u>Filament Voltages:</u> <u>Use A.C. Voltmeter</u>	Test Terminals	Approximate Voltage
Detector	Test from Red-White tracer to Black-White tracer	2.35
Radio Freq. Amplifiers and 1st Audio Freq. Amplifier	Test from Red to Black	1.45
Power Amplifier (2nd A.F.)	Test from Red-Green tracer to Black-Green tracer	4.8
<u>Plate Voltages:</u> <u>Use D.C. Voltmeter</u>		
Detector	From Red-White tracer to Yellow	44
Radio Freq. Amplifiers	From Red to any R.F. tube Plate contact marked "P," (through eyelet)	160
1st Audio Freq. Amplifier	From solid Red to Black-Red tracer	155
Power Amplifier (2nd A.F.)	From Red-Green tracer to solid brown wire	180
<u>Bias Voltages:</u> <u>Use D.C. Voltmeter</u>		
On Power tube grid	From F to G (socket marked 2A, through eyelets)	45
On Grid of Radio Freq. Amplifiers and 1st Audio Amplifier.	From F to G (socket marked 1A, through eyelets)	13

EXAMINATION - LESSON 53

1. Draw a simple schematic diagram showing the power unit, plate, filament and grid circuits similar to the diagram in Figure 3. Now label all of the parts with their proper names.
2. (a) Why are the grid suppressor resistances necessary? (b) Why do we not find a grid suppressor resistance in the grid of the fourth tube, counting from the left in the schematic diagram of Figure 1?
3. What are the general conditions to be satisfied in the design of a receiver in order to permit two or more radio frequency amplifier stages to be tuned simultaneously with a single control dial?
4. What real purpose does the first tube in the Atwater Kent Model 40 receiver serve?
5. (a) In a receiver of this design do the signal currents of more than one broadcast station pass through the output or plate circuit of the first radio frequency tube? State briefly why? (b) Name each circuit in sequence which is designed especially to permit the selection of the transmitted frequency of the broadcast station which the listener-in desires to hear.
6. (a) How are the grid bias voltages obtained?
(b) How are the plate voltages obtained?
(c) From what source is the filament heating current supplied?
7. Let us assume that a certain detector tube is being operated so that a comparatively high value of plate current (normal current) flows steadily in it's plate circuit. Would this high normal current be a positive indication to you that a strong signal would be heard when tuning-in a station? State your reasons concisely. (Note: Assume that the signal energy picked up by the antenna is sufficient for all practical reception and therefore this point does not require consideration in your answer).
8. In brief what is the general construction of the UX-280 rectifier tube and how are the filaments connected? Does this method of filament connection have any practical value and why?
9. Why are potentiometers used across filament heating windings of a power transformer and why are these resistances tapped?
10. What functions are performed by the last condenser in the filter system of the power unit? (This condenser is marked C-6 in Figure 1.) If you had occassion to service a Model 40 receiver and found one of the main filter condensers broken down and shorted would you attempt to replace this damaged condenser? What would you do?